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Comparison of Calculated Geostrophic Current from CTD and A.D.C.P. data.

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PURPOSE.

The purpose of this project is to compare the computed Geostrophic Currents calculated from data from 38 separate CTD casts with the currents measured by the Acoustic Doppler Current Profiler (ADCP) data. Specifically, the collected data will be compared to the sea surface height anomaly.

The main goals are:

To calculate the computed Geostrophic current from CTD cast.

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To plot ADCP currents normal to the ship track.

To compare both data.

1.- Introduction.

Geostrophic currents from hydrography:

Geostrophic flow results from a balance in the hydrostatic and Coriolis forces.

The net result of this balance is a flow with a direction perpendicular to the hydrostatic (pressure) gradient.

To use geostrophic to infer currents at depth we need to determine not only the pressure gradient due to the sloping sea surface, but also the subsurface pressure gradients due to variable density stratification.

Geopotential surfaces in the ocean:

In practice, we will estimate the slope of the geopotential surface at one depth compared to another, and this tells us the relative strength of the current at the two depths.

The steps taken are:

1. Calculate the differences in geopotential Φ between two different pressure surfaces 1 and 2
2. Calculate the slope of the upper surface relative to the lower from observations at two locations A and B
3. Calculate current at the upper surface relative to the lower – this is the current *shear*
4. Integrate vertically the shear in the current assuming some knowledge of the current at a reference depth

2.- Calculations.

Calculations to determine Geostrophic Currents were made from the CTD data with MATLAB using Commonwealth Scientific and Industrial Research Organization (CSIRO) seawater programs. The MATLAB code for plotting of both the CTD data and the ADCP data are contained in Appendix 1. As stated in Pond and Pickard, 1983,

a.-Geostrophic velocity:

$$(-1/\rho) (\partial p / \partial x) = fv$$

$$\therefore v = (-1/f\rho) (\partial p / \partial x)$$

with variable defined as:

ρ = density,

$f = 2\Omega \sin \phi$ Coriolis parameter

$\Omega = 7.292 \times 10^{-5} \text{ s}^{-1}$ Angular speed of earth rotation

ϕ = latitude

$\partial p / \partial x$ = pressure gradient between CTD casts

For geostrophic Equation:

$$(V_1 - V_2) = \frac{1}{L 2 \Omega \sin \phi} [\Delta \phi_B - \Delta \phi_A]$$

$$(V_1 - V_2) = \frac{10}{L 2 \Omega \sin \phi} [\Delta D_B - \Delta D_A]$$

Where:

L = Distance between 2 Stations

$\Delta \phi$ = Geopotential Anomaly

$\Delta D = \int_0^z \delta dp$ = geopotential distance, integrated from the surface to
the level of no motion

$\delta = 1/\rho$, specific volume anomaly

z = reference level (1000 dbar. Previously defined)

Therefore:

$$v = \frac{\Delta D}{2 \Omega \sin \phi \Delta x}$$

Δx = Distance between 2 stations = L

This calculates Geostrophic velocity 90° to the line, which is in line with the adjusted (rotated 30°) “across line” ADCP velocities.

3.- Main Instruments.

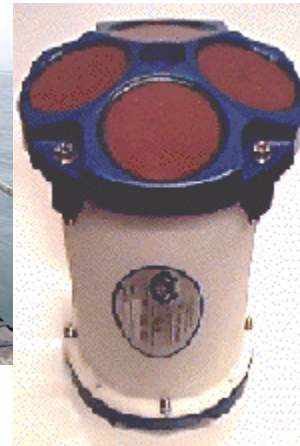
ADCD Principles Function:



ADCP Position on board



CTD



ADCP with its 4 transducers

The ADCP (Acoustic Doppler Current Profile), estimates horizontal and vertical velocity as a function of depth by using the Doppler effect to measure the radial relative velocity between the instrument and scatterers in the ocean. Three acoustic beams in different directions are the minimal requirement for measuring the three velocity components. A fourth beam adds redundancy and an error estimate. The ADCP transmits a ping from each transducer element roughly once per second. The echo arrives back at the instrument over an extended period, with echos from shallow depths arriving sooner than ones from greater ranges. The ADCP doesn't measure velocity at a single point, it measure velocities throughout the water column. The ADCP, measures velocities from its transducer head to a specified range and divides this range into uniform segment called Depth Cells. The collection of depth cells yields a PROFILE. The ADCP produce two profiles, one for velocity and one for echo intensity.

The ADCP calculates velocity data relative to the ADCP. The velocity data has both speed and direction information. If the ADCP is moving, and is within range

of the bottom, it can calculate the absolute velocity of the water. The ADCP can get also, absolute direction information from heading sensor.

4.- The California Current.

The California Current (CC), Large Marine Ecosystem is separated from the Gulf of Alaska LME by the Subarctic Current, which flows eastward from the western Rim of the Pacific Ocean. The California Current gives unity to this LME and flows south along the West Coast of North America. The California Current system is very complex and one of the major currents of the North Pacific Ocean.

The CC flows toward the Equator and forms the eastern section of the North Pacific Subtropical Gyre. It is a coastal upwelling system extending from northern California to Baja California with a fairly narrow continental shelf (Wooster and Reid, 1963; Parrish et al., 1983). The LME is a transition environment between subarctic and subtropical water masses and freshwater inputs from land. Its physical and biological properties vary seasonally with current fluctuations (Favorite et al., 1976; Bottom et al., 1993). El Niño episodes, and the El Niño-Southern Oscillation (ENSO) phenomenon, result in strong interannual fluctuations in the conditions affecting marine populations in this LME. The perturbations introduced may take many years to dissipate. ENSO events are characterized locally by an increase in temperature, a rise in coastal sea level, diminished upwelling and increased coastal rainfall (Bakun, 1993).

Recent observations in the Santa Barbara Channel and over the California Cooperative Oceanic Fisheries Investigations (CalCOFI) southern California grid are used to examine seasonal circulation patterns in and near the Southern California Bight, defined as the region east of the Santa Rosa Ridge and including the Santa Barbara Channel. Poleward flow relative to 500 m is found throughout the bight, in all seasons except for spring and all subregions except the western part of the Santa Barbara Channel. In spring there is equatorward

flow throughout the bight at all depths to 500 m, though it tends to be surface or midcolumn intensified. Equatorward flow offshore of the bight, present in all seasons, narrows and accelerates into a jet-like feature and simultaneously moves close to the Santa Rosa Ridge in summer. Current meter data from the eastern entrance to the Santa Barbara Channel are consistent with the seasonal results from the CalCOFI data and further show an upward propagation of phase at annual period, with a phase speed of 1 to 2 m d⁻¹. Comparison with the CalCOFI ship winds suggests that poleward flow in the bight may be the result of positive wind stress curl, through a Sverdrup balance, though the observed transport is only about 75% of that expected from the curl amplitude. Equatorward flow in the bight may be the result of coastal upwelling, though the transport is larger than expected from the relatively weak winds in the bight. Equatorward flow outside the bight cannot be explained as a Sverdrup flow because the wind stress curl is positive throughout most of the region. Upward propagation of phase and downward propagation of energy may be indicative of forcing by remote wind equatorward of the bight. Given the complexity of possible forcing mechanisms for circulation in and near the bight, a model that includes effects of remote wind forcing, Ekman pumping, and topography is needed to explain the observations in a satisfactory way.

5.- Data and Procedures.

5.1. Data Collection

The data collected by the CTD and ADCP was done along the Line show in the image below on the OC 3570 cruise onboard the R/V Point Sur in October 2002 which didn't correspond to my actual Cruise. The actual cruise that I was embarked was in July 2003. The ship's track and the location where each CTD cast took place are displayed in Figure 1. With each CTD cast conductivity (which provided salinity), temperature and pressure was measured to a pressure

of 1000 dbars, or 1000 meters. The vessel mounted ADCP measured currents along the line of the ship's course.

The CTD and ADCP data were collected along the lines explained before.

CTD casts were made at least a depth of 1000 m when depth restriction allowed. Conductivity, temperature and pressure were acquired at a rate of 24 Hz averaging these to 1 Hz. After each station the cast was processed to have a sample each 2 mb, so the ASCII file ended with latitude, longitude, pressure, primary temperature, secondary temperature and other data samples which were not took in account

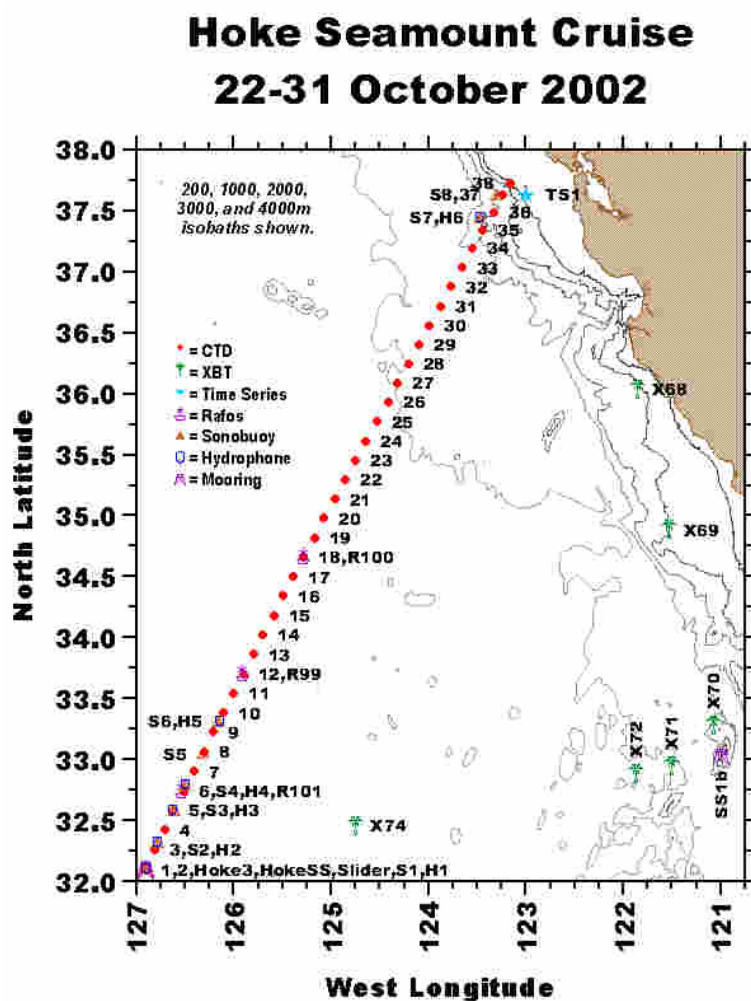


Fig. 1

6.- Analysis.

6.1. The T-S diagram (Fig 2):

Indicates mixing waters in shallower areas than deeper waters. This is due to turbulent mixed waters next to the surface and heat fluxes due to the sun warming.

Deeper waters are saltier and colder due to the California Undercurrent.

6.2. The Salinity Plot (Fig 3) :

Salinity Plot show a typical profile with fresher water in shallow waters and saltier in deeper waters. Between Latitude 35 and 36, there is a “fresh pool” indicating maybe the presence of a mesoscale feature like an eddy or a meander.

6.3. Temperature profile (Fig 4):

The temperature plot indicate a strong variation between 300 and 400 (dbar), probably due to internal waves waves generating with the bottom slope. These internal waves may propagate toward the coast, hit the shelf and enhance mixing.

6.4. Density Anomaly (Fig. 5):

Density Anomaly indicates a depress in the isopycnals between latitude 35N and 36N at the surface and up to 200 or 300 meters. The rest of the area seems to be well stratified.

6.5. Across line velocity profile (ADCP. Fig 6):

The Across velocity indicates strong velocities in the same location of the Geostrophic velocity plot, this is between Latitude 36 and 37 N. this High velocities are extended up to 250 meters.

6.6. Geostrophic velocity plot (Fig 7):

Between station 17 and 27, this is latitude 36. indicates a strong Geostrophic velocity in the upper 300 dbar. This can indicate the presence of an eddy or a meander, which is consistence with the temperature profile and the Satellite image discuss later.

6.7. Satellite Image (Fig 9):

The satellite image, indicate the Sea Surface Height of the area where the Cruise was taken in October 2002. According to the image and the track of the ship it can be said that there was an anticyclonic feature in the path of the ship, which is consistence with the analysis of the plots

6.8. Vector Plot (Fig 10):

The Vector Plot indicates the possible presence of an eddy in the middle of Latitude 36N. The vectors indicate clockwise rotation from the surface and up to 300 meters in depth. Higher velocities are in the upper 125 meters. This is consistence with the rest of the analysis and with the image of the Satellite (SSH), which indicate a warm core eddy.

7.- Comparison of ADCP Cross-Section Velocity and Geostrophic Velocity Profiles (Fig 8).

From the Plot (Fig 8) it can be said that there are relatively good correlation between ADCP Cross-Section Velocity and Geostrophic Velocity Profiles specifically below 150 meters. In shallower waters there are differences between both calculated velocities. We can see a huge difference especially between latitudes 35N and 36N in the upper 150 meters. This could be due maybe to the presence of baroclinic tides, Internal waves and Ekman Layer friction, acting in the surface. Also according to the T-S Diagram and Salinity and Temperatures profiles, next to the surface there are more turbulent waters that may affect the measurements.

8.- Conclusions.

ADCP velocities and velocities computed from the CTD data have a good correlation in waters below 150 dbar. However, the comparison between the calculated geostrophic currents and the ADCP velocities in shallower waters differs specially between station 17 and 27, this is between Latitudes 36N and 36N in the upper 150 meters.

Maybe the presence of a Southern California Eddy is related to the high sea surface height in the surveyed region between station 17 and 27.

The proximity to the coast also can prejudice the comparison since there are many boundaries involved. The variation of wind stress and the existence of internal waves can lead to differences.

The combination of the analysis of the plots from the CTD and ADCP cast plus the Sea surface High satellite image and the vector plots, it can be said that there was an eddy in latitude 36N and longitude 123.5 W. with velocities up to 50 cm/sec. (almost 1 knot).

Large differences in the ADCP velocities and velocities computed from the CTD, primary in shallow waters could be caused due to:

- Wind stress differences

- Presence of mesoscale features

- Presence of baroclinic tides

- Internal waves

- Ekman Layer friction

- Instruments errors

- Measurements errors

9.- References.

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CSIRO Commonwealth Scientific and Industrial Research Organization (CSIRO) seawater programs.

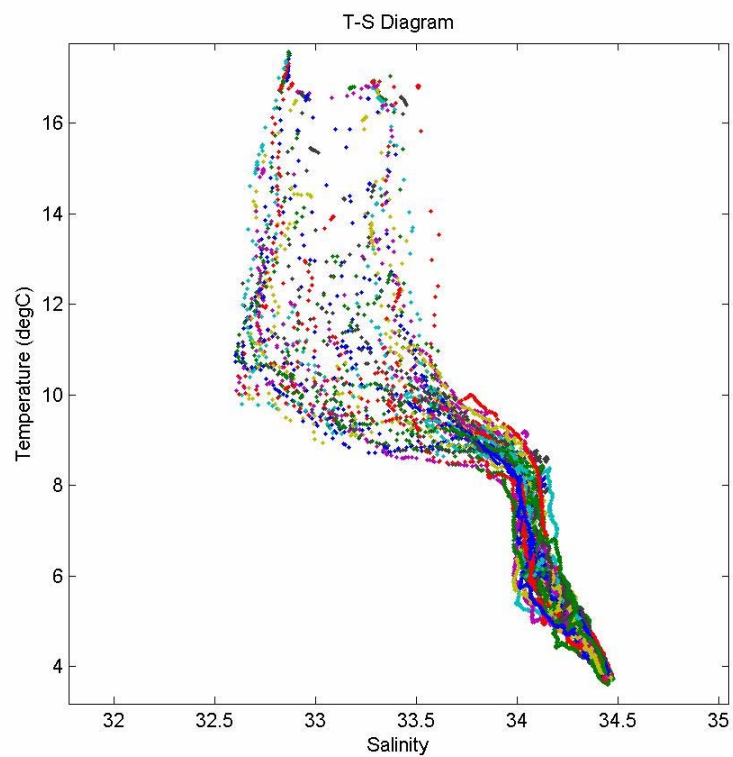
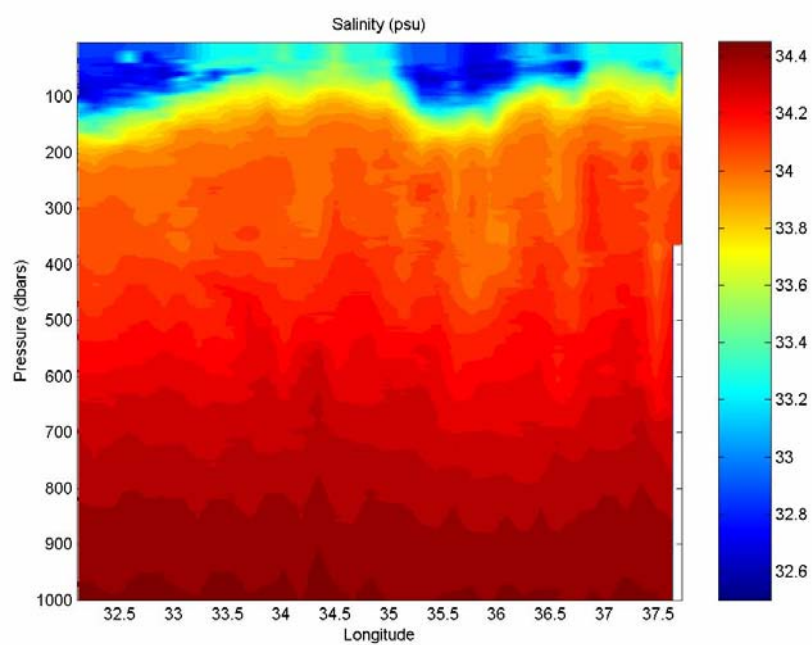
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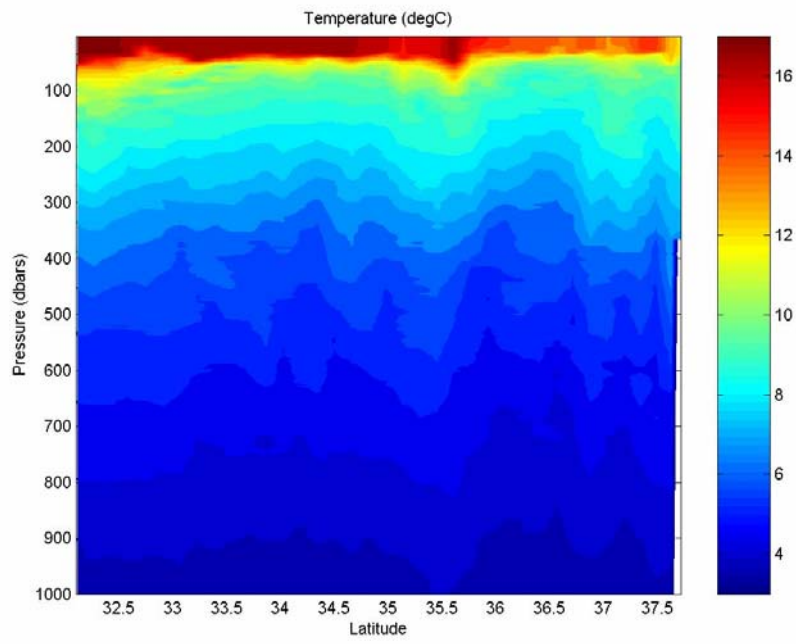
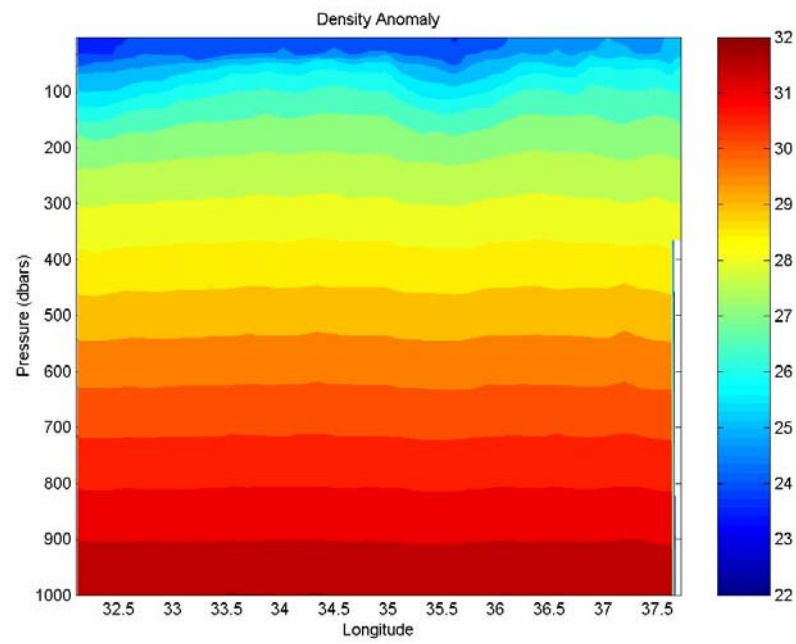
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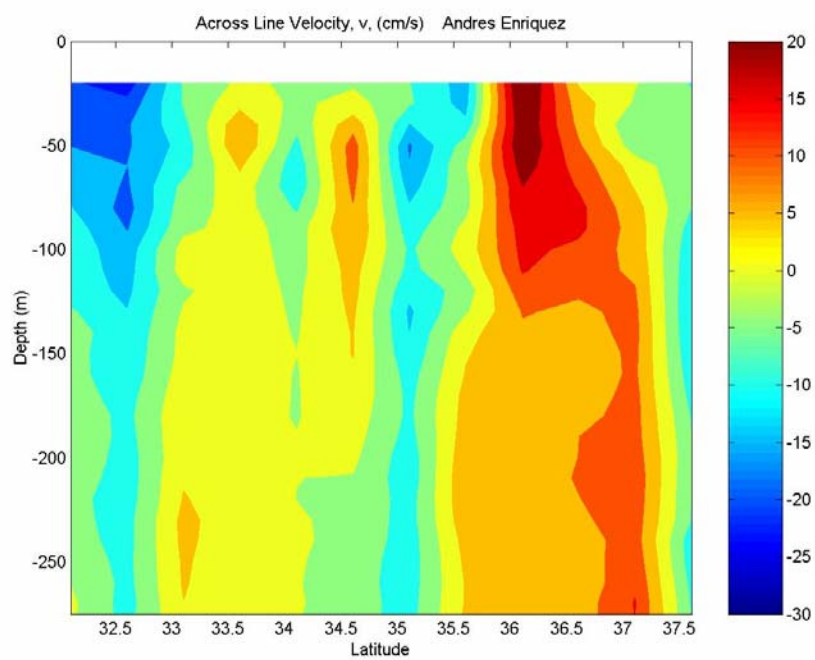
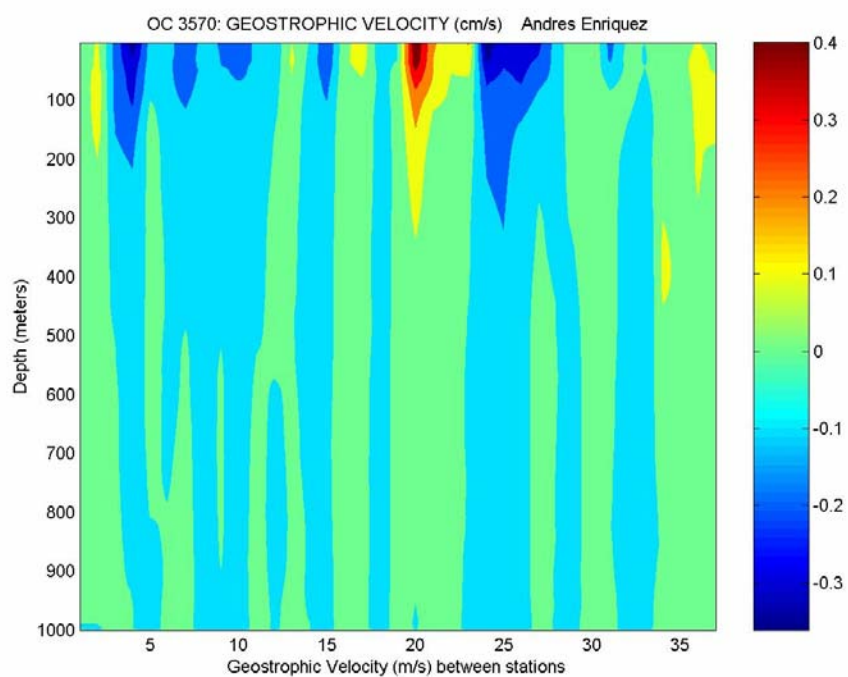
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RD Instruments (A.D.C.P)

*Fig 2**Fig 3*

*Fig 4**Fig 5*

*Fig 6**Fig 7*

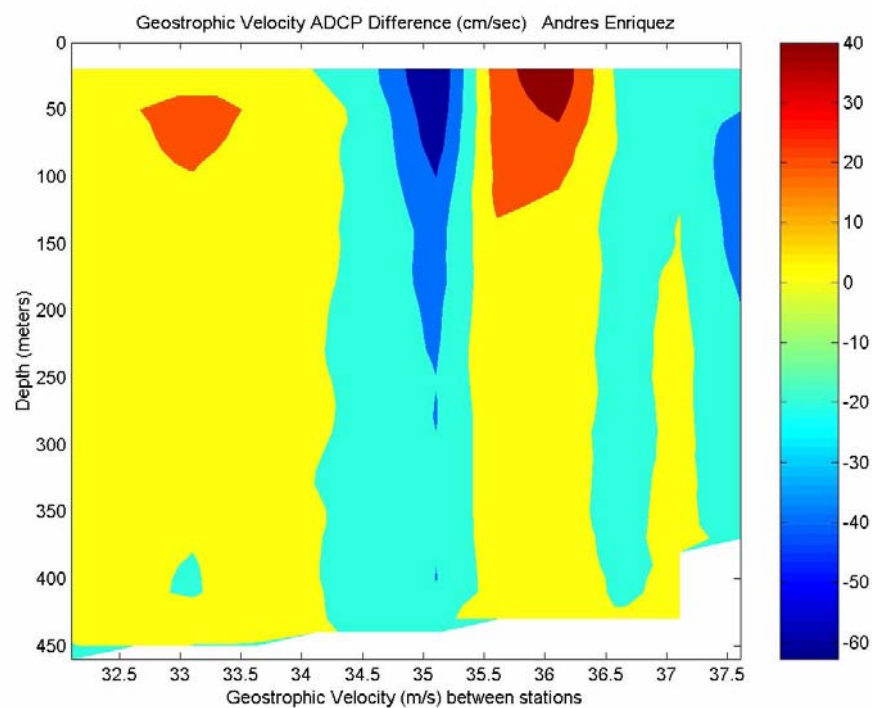


Fig 8

Real-Time Mesoscale Altimetry - Oct 25, 2002

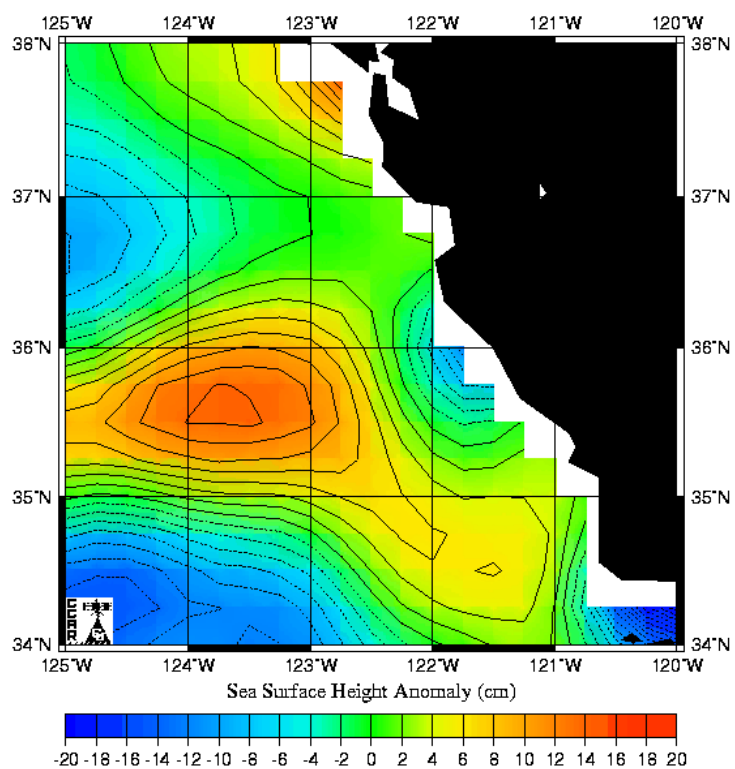


Fig 9

Fig's 10